Activity 5 Structural Geology and Your Community

Goals

In this activity you will:

- Describe the relationship between fault movement and the forces that cause this motion.
- Understand that Earth movements can create faults and folds.
- Understand that models help scientists understand how things work.

Think about It

Marble is metamorphosed limestone, a rock that is deposited in nearly horizontal layers.

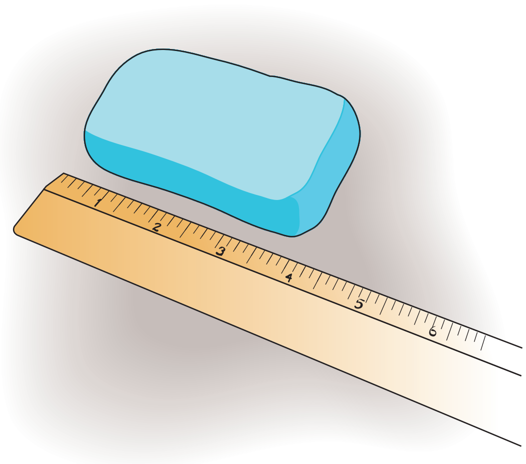
- What would happen if you tried to use a powerful machine to fold a marble bench?
- How are rocks able to fold naturally without first breaking?

What do you think? Record your ideas about these questions in your *EarthComm* notebook. Be prepared to discuss your responses with your small group and the class.

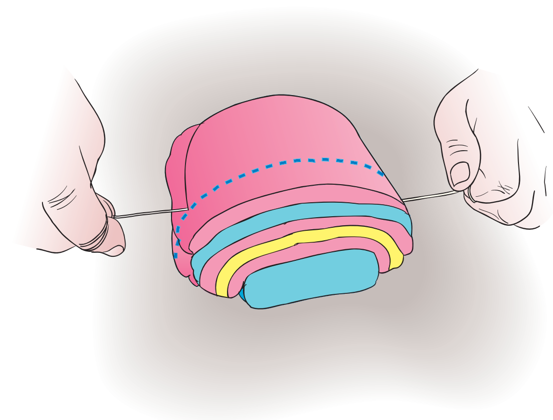
Investigate

Part A: Making a Model of Folds

1. Mold a large lump of soft craft clay into the shape shown in the figure. The block should be about 10 cm long and about 8 cm wide, as shown in the diagram below. This is your "base block."



2. Put another lump of clay onto a sheet of waxed paper and roll it out with a rolling pin or a wooden dowel into a sheet about 6 mm thick. Drape the sheet over your base block, and trim the edges.
3. Repeat step 2 with lumps of clay of different colors until you have five or six layers. As you place the layers on the block, shape them slightly with your fingers so that they keep almost the same shape as the top of your base block. You now have a block of folded rock layers.
4. Use your hands to stretch a length of dental floss or fishing line tightly, and use it to slice through your folded block. Make two slices: one should be straight down through the block, parallel to its long dimension and off to one side, and the other should be horizontal, through the middle of the folds, as shown in the diagram below.



   a) In your notebook, sketch what the folds in your block look like on the faces of each of the cuts you made. The vertical cut is what real folded rocks look like in cross-section view, and the horizontal cut is what real folded rocks look like in map view.

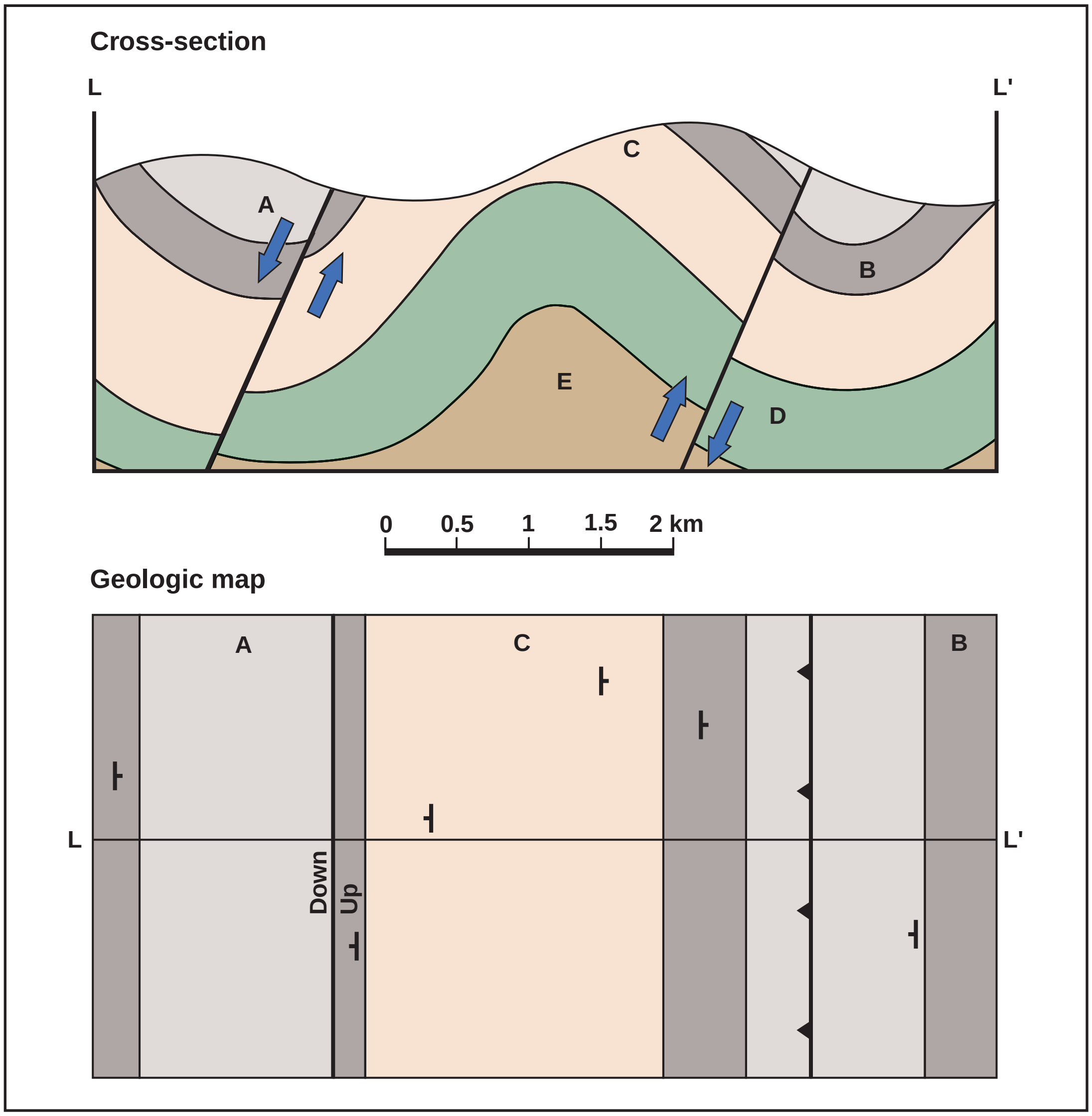
Part B: Making a Model of Faults

1. Obtain foam blocks that have been cut into two pieces at an angle, as shown in the photograph. Use colored pencils or pens to create at least three horizontal layers on the sides of your square.

2. Place the two cut sides of the Styrofoam together, face to face. The plane where the two cut surfaces are in contact is a model of a fault plane. Slowly push the two pieces together, so that the upper piece slides upward relative to the lower piece.
   a) Draw a side view and a top view of what happens. Use arrows to show the direction of force. Use a different type of arrow to show how the colored layers moved in relation to one another along the fault plane.
3. Start over again, with the two pieces of Styrofoam face to face. Slowly slide the lower piece upward relative to the upper piece.
   a) Draw a side view and a top view of what happens. Again, use arrows as above to indicate the direction of force and the movement of layers.
   b) What is the difference in the way the Styrofoam blocks moved in these two trials?
4. Return the Styrofoam to the original position. Move the Styrofoam pieces so that they slide sideways past each other.
   a) Draw a picture of the pieces. Use arrows as before to indicate the direction of force and the movement of layers.

Part C: Interpreting Structure Using Geologic Maps and Cross Sections

1. Geologic maps have special symbols to indicate the locations of faults and folds. Many maps also have one or more cross sections drawn. A cross section shows how the rocks are deformed and makes it easier to infer the forces that caused the deformation. Use a copy of the geologic map and cross section on the following page to complete the following:
   a) Color the cross section and the map. Use a different color for each of the five rock layers A through E.
   b) Sediments are almost always deposited in nearly flat, horizontal layers. What evidence suggests that the rock layers in this region were deformed by forces within the Earth?
   c) Were the faults produced by compression (pushing forces), tension (pulling forces), or shear (sideways forces) in the rock layers? Explain.
   d) Are the folds in the rock layers consistent with your answer above? Explain.



Reflecting on the Activity and the Challenge

In this activity, you modeled the way that forces on rocks can cause the rocks to bend. If the forces on the rocks are large enough, they can cause the rock to fold or fracture. Sometimes forces can move broken pieces up or down. Understanding that changes within the Earth's crust can cause folds and fractures will help you determine the geological history of your community.

Digging Deeper

FORCES IN THE EARTH'S CRUST

Types of Forces

Earlier in this chapter you learned that sedimentary rocks form from sediments that are originally laid down in almost flat, horizontal layers. In many places on Earth, however, sedimentary rocks, and other kinds of rocks as well, are not found in a horizontal position. Instead, they are tilted at some angle to the horizontal. Sometimes they are tilted so much that the layers are vertical! The tilting of the layers is a sign that they have been deformed by forces acting within the Earth. The forces can cause the rocks to become folded, and they can cause the rocks to fracture and then to slip along the fracture surfaces. A fracture surface along which rocks slip is called a **fault**. Forces within the Earth that cause folding and faulting are created by the movement of the Earth's lithospheric plates. The plates move very slowly (2 to 20 cm/yr), but over time spans of hundreds to thousands of years, great forces build up in the Earth's crust. These forces are transmitted for long distances through the crust, so folding and faulting can happen not only near plate boundaries but also in the interiors of the continents, far from plate boundaries.

Three different kinds of forces can cause rocks to deform: **tension forces, compression forces, and shear forces**. Suppose you are holding a solid, rectangular block between your hands. When you try to pull the block apart at its ends, you are exerting a tension force. When you push the ends of the block together, you are exerting a compression force. When you hold two opposite edges of the block and try to move them in opposite directions, you are exerting a shear force. In all three cases, if the force you exert is greater than the strength of the solid material, it deforms, either by fracturing or just changing its shape without actually breaking. The forces that are created in the Earth's crust by the movement of lithospheric plates are often great enough to deform the rocks.

Folding and Faulting

What determines whether a rock is faulted or folded? It's partly a matter of temperature. At low temperatures, as in the upper parts of the Earth's crust, the temperature of rocks is relatively low. At low temperatures rocks are brittle, and they tend to deform by fracturing. At higher temperatures, as in the lower parts of the Earth's crust, the temperature of rocks is relatively high. When forces are exerted on rocks at high temperatures, the rocks tend to deform by changing their shape continuously rather than by faulting.

Geo Words

fault: a fracture or fracture zone in rock, along which the rock masses have moved relative to one another parallel to the fracture.

tension force: a force that tends to pull material apart.

compression force: a force that tends to push material together.

shear force: a force that tends to make two masses of material slide past each other.

Geo Words

normal fault: a fault formed by tension forces that cause the body of rock above the fault plane to slide down relative to the body of rock below the fault plane.

reverse fault: a fault formed by compression forces that cause the body of the rock above the fault plane to slide upward relative to the body of rock below the fault plane.

thrust fault: a reverse fault in which the fault plane is nearly horizontal.

strike-slip fault: a fault formed by horizontal shear forces that cause the bodies of rock on either side of the fault plane to slide past each other horizontally.

Figure 1 Intense heat and pressure folded these previously horizontal sedimentary layers.

Folding is an example of how rocks can change their shape continuously without breaking, as shown in *Figure 1*. Whether a rock is folded or faulted is also a matter of time. If forces build up very fast, rocks are more likely to fracture, but if forces build up very slowly, the rocks are more likely to change their shape without breaking.

Faults

When a fault is formed by tension forces, which cause the rocks of the crust to be pulled apart, the body of rock above the fault plane slides down relative to the body of rock below the fault plane, as shown in *Figure 2(a)*. Faults of this kind are called **normal faults**. When a fault is formed by compression forces, the body of rock above the fault plane slides upward relative to the body of rock below the fault plane, as shown in *Figure 2(b)*. Faults of this kind are called **reverse faults**. When the fault plane is nearly horizontal, the faults are called **thrust faults** instead. When a fault is formed by horizontal shear forces, the bodies of rock on either side of the fault plane slide past each other horizontally, as shown in *Figure 2(c)*. Faults of this kind are called **strike-slip faults**.

Movement on faults usually occurs suddenly after a long time without any movement. The forces that cause the faulting build up very slowly, and when they become greater than the strength of the rock, the fault moves. That relaxes the forces, which then slowly build up again. Major faults typically move only every few centuries. Most earthquakes are caused by sudden movement on faults.

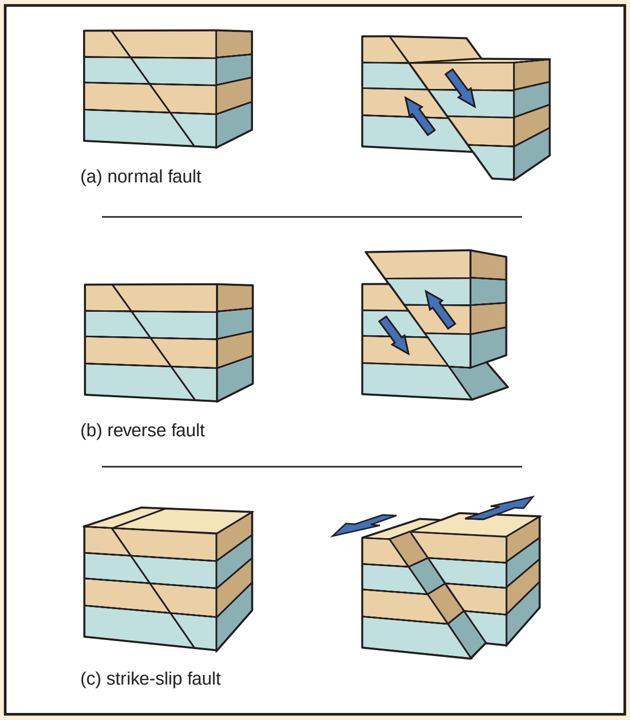


Figure 2 The three major types of faults. When a reverse fault occurs at an angle of less than 45°, it is called a thrust fault.

Figure 3 What kind of fault is shown in this photograph?

Folds

Folds are usually formed when rocks are squeezed together by compressive forces. Folds are especially common when the rock is layered, like sedimentary rock, and the layers differ in their stiffness (resistance to being bent). Here is a "thought experiment" to show the effect of layering. Make a square block of soft, modeling clay and squeeze it together from opposite sides. It becomes compressed, but it doesn't form folds. Now make a block that consists of many thin layers of clay separated by index cards. Squeeze the block from opposite sides, in a direction parallel to the index cards. The block then deforms by folding.

Folds in the Earth's crust are usually arranged horizontally. The parts of the folds that are concave upward are called **synclines** (*Figure 4a*), and the parts of the folds that are convex upward are called **anticlines** (*Figure 4b*). Folds in rocks can be as small as centimeters or as large as many kilometers.

Figure 4a Sideling Hill in Maryland is an example of a syncline.

Figure 4b Anticline in Wyoming.

Using Models to Investigate Geologic Structures

Geologic processes like the folding and faulting of rocks work over very long time spans. The folding of rocks cannot be observed in nature as it happens. Models help scientists to understand the deformation of rocks. Geologists have used layers of colored wax and a special "squeeze box" to investigate

Geo Words

fold: a bend in a planar feature in rocks. A fold is usually a result of deformation.

syncline: part of the fold that is concave upward.

anticline: part of the fold that is convex upward.

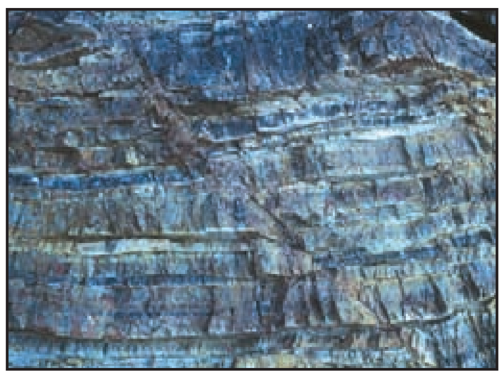
the folding process. The box had a glass wall for viewing the wax from the side. One side of the box moved along threaded rods, creating a force on the wax as the walls closed in on one another. Wax was poured into the box one layer at a time. A knob on one end of the box allowed the wall of the box to be moved horizontally. This movement squeezed the wax from the ends. The model allowed scientists to vary the rate at which the force was applied and the thicknesses of the various layers. The model helped them to create folds that they saw in nature and make interpretations about the forces that created these folds.

Check Your Understanding

1. Describe tension, compression, and shear forces in your own words. You may wish to use a diagram.
2. What factors determine whether a rock will fault or fold?
3. Why do scientists work with models to understand folding and faulting?

Understanding and Applying What You Have Learned

1. Look at the photograph of faulted rock layers in Pennsylvania.
   a) Do the rocks appear to have been pulled apart, pushed together, or slid past each other to form this structure?
   b) What type of fault is this?
2. Look at the photograph of a fault found in California.
   a) Were the rocks pulled apart, pushed together, or slid past each other to form this structure?
   b) What type of fault is this?
3. Examine your state geologic map and geologic cross sections.
   a) How many faults do you see near your community?
   b) What types of faults do you see?
   c) How many folds do you see near your community?
   d) What types of plate motion does this suggest?



Pennsylvania

California

Preparing for the Chapter Challenge

Using your understanding of the plate motions associated with faults and folds, interpret the geological history of your area in terms of motion in the Earth's crust.

Inquiring Further

1. **Geologic structures in the National Parks**

   Look at a geologic map and cross section of the Grand Tetons in Wyoming. Research the types of structures, folds, and faults in this area. Interpret the geologic history of the area.

2. **Careers in Structural Geology**

   Use the *EarthComm* web site to find a structural geologist who lives and works in your state or region. Introduce yourself through a letter or e-mail message. Briefly describe the work that you are doing in your *EarthComm* classroom. Ask one or two questions that will help you learn about careers in structural geology. Examples include:

   - What makes structural geology so interesting to you?
   - What made you decide to become a structural geologist?
   - What do you think is the most challenging aspect of structural geology?
   - What do you enjoy most about your work?